RETREAT MINING WITH MOBILE ROOF SUPPORTS

By Frank E. Chase,[1] Allen McComas,[2] Christopher Mark, Ph.D.,[3] and Chester D. Goble[4]

ABSTRACT

Mobile roof supports (MRS's) are shield-type support units mounted on crawler tracks. MRS's are used during retreat mining and eliminate the setting of roadway, turn, and crosscut breaker posts that are required during pillar recovery operations. Mobiles are a more effective ground support than timbers, and their usage enhances the safety of section personnel and reduces material handling injuries. MRS usage is rapidly increasing, and approximately 40 U.S. coal mines have successfully employed this relatively new technology. This paper addresses the practical aspects of MRS usage in underground coal mines.

During this study, nearly one-half of the U.S. mines that have utilized mobiles were visited. This report depicts the more common pillar extraction methods that operators have found successful. The "Christmas tree" and outside lift methods are described and illustrated. Roof control plans that do not require breaker posts or allow pillar extraction with fewer than four mobiles are also examined. In addition, operators' experiences with setting pressures, loads, and rates of loading during pillar extraction are addressed. Mining and support strategies to more effectively control hillseams, weak roof, and gob overrides are also discussed.

[1]Geologist, Pittsburgh Research Center, National Institute for Occupational Safety and Health, Pittsburgh, PA.
[2]President, Mobile Mining Supports, Inc., Peach Creek, WV.
[3]Mining engineer, Pittsburgh Research Center, National Institute for Occupational Safety and Health, Pittsburgh, PA.
[4]Vice president, Mobile Mining Supports, Inc., Peach Creek, WV.

INTRODUCTION

Mobile roof supports (MRS's) are shield-type support units mounted on crawler tracks (figure 1). MRS technology was pioneered by the former U.S. Bureau of Mines during the 1980's [Thompson and Frederick 1986]. Commercial units are currently manufactured by J. H. Fletcher and Co., Huntington, WV, and Voest-Alpine Mining and Tunneling, Pittsburgh, PA. Fletcher refers to its units as "Fletcher Mobile Roof Supports" (FMRS). Voest-Alpine has designated its units as "Alpine Breaker Line Supports" (ABLS). For the purposes of this paper, the generic term "MRS," or "mobile," is used to identify both manufacturers' units. In 1988, the Donaldson Mine in Kanawha County, WV, was the first U.S. operation to use mobiles. Since then, approximately 40 U.S. mines in 5 States have utilized mobiles. These States include Illinois, Kentucky, Pennsylvania, Virginia, and West Virginia. Mobiles have been employed in more than 15 different U.S. coalbeds ranging from 1.7 to 4 m (5.5 to 13 ft) thick. MRS units are primarily used in coalbeds thicker than 2.4 m (8 ft). Currently, there are approximately 100 units in use in the United States. Mobiles have been used primarily during full and partial pillar recovery operations. However, the first longwall face shield recovery operation to utilize mobiles instead of walking shields was in a southern West Virginia coal mine in 1996. Operators and others have also been discussing mobile employment in longwall headgates and tailgates.

MRS's provide improved safety to section personnel compared with a conventional timber plan. However, the first fatality on an MRS section occurred in 1995 in Mingo County, WV. During the fatality investigation, questions arose regarding (1) pillar extraction methods, (2) setting pressures, (3) loads and rates of loading on the machines, and (4) proper positioning of mobiles and face personnel. In order to determine the current state of the art in MRS usage, researchers from the Pittsburgh Research Center visited 20 U.S. mines with different geologic and mining conditions. Personnel with practical hands-on experience were questioned at each operation, and operational advantages and issues were discussed. In addition, all Mine Safety and Health Administration (MSHA) approved MRS roof control plans were examined. The findings are summarized below.

Figure 1.—Full pillar extraction using mobile roof supports.

SAFETY ADVANTAGES

MRS's are used in lieu of roadway, turn, and crosscut breaker posts during pillar recovery operations. Eliminating the setting of these posts enables miners to remain further outby the pillar line and reduces their exposure to gob overrides and rib spalling. Mobiles are active supports, whereas wooden posts are strictly passive. Mobiles also provide better roof coverage. Roof coverage depends on the manufacturer; however, the unit with the least canopy dimensions provides 3.3 m^2 (36 ft^2) of pressurized roof coverage, compared with less than 0.1 m^2 (1 ft^2) for a wood post. The improved stability of mobiles is also a major advantage. Wood posts will fail, sometimes with little or no warning, at less than 2.5 cm (1 in) of convergence. Mobiles will displace approximately 2.5 cm (1 in) before yielding and have the ability to yield through a few meters of displacement without becoming unstable. Mobiles are much better suited to handle eccentric load conditions (i.e., horizontal and lateral loading), which are common during pillar extraction, compared with wood posts, which suffer reduced stability for anything but pure axial (vertical) loads [Barczak and Gearhart 1997]. Gob sliding and rib rolls will commonly kick out breaker and turn posts.

MRS units are available in two different support capacities. With one exception, all U.S. mines employ mobiles that can exert up to approximately 5,338 kN (600 tons) of force against the roof. These units each have a load-bearing capacity equivalent to six 20-cm (8-in) diameter hardwood posts [Barczak and Gearhart 1997]. One deep-cover operation in Virginia is using mobiles that have a 7,118-kN (800-ton) support capacity. Based on the above, MRS's are superior to wood posts for pillar extraction. At every operation visited, personnel expressed the opinion that mobile usage enhances pillar line stability and safety.

Mobiles reportedly reduce material handling injuries and free personnel for other less strenuous assignments. In a mine visited in Mingo County, WV, the operator noticed a significant reduction in back injuries with mobile usage. Prior to mobiles, scores of posts 3.4 m (11 ft) long and weighing 80 kg (175 lb) had to be set to recover each pillar. Because of reduced roadway clearance, shuttle cars were constantly knocking out the posts, which then had to be reset. Three miners were required to set each post. One miner had to climb a stepladder to drive in the wedges. This miner summarized by saying "we're not setting posts, we're planting trees." In another mine visited in Mingo County, WV, 105 posts were typically set for every pillar mined, compared with only 8 breaker posts when mobiles were employed. The mine worked three shifts, and it required one miner on each shift to haul in enough timbers to keep up with pillar line advancement. This same operator reported a reduction in cost of \$0.65/t (\$0.60/st) over conventional timbering and an 18% increase in production. A reduction in cost of \$2.20/t (\$2.00/st) was reported by an operator in Boone County, WV. Mobiles also increase the self-esteem of reassigned miners. Miners have traded in their axes and bow saws for more modern technology.

PILLAR EXTRACTION METHODS

CHRISTMAS TREE METHOD

The "Christmas tree" method (also called left-right, fishbone, or treetopping) is the most commonly used full pillar extraction method with MRS's (see figures 2*A* through *D*). This method is generally employed under deep cover when pillars on 18- or 24-m (60- or 80-ft) centers are required to maintain necessary pillar stability factors. Figures 2*A* through *D* depict a common sequence in which lifts are extracted during barrier and production pillar extraction. As shown in figure 2*A*, mobile unit 4 is trammed approximately 2.1 m (7 ft) outby and pressurized prior to mining lift 2. Prior to mining lift 3 (figure 2*B*), unit 3 is trammed 4.3 m (14 ft) outby and pressurized. This process continues until the breakers are set, as indicated in figure 2*B*. After the breakers are set, unit 3 is moved to position F and unit 4 is trammed to position G. When referring to a particular mobile, units 1 through 4 are designated as shown in figure 2*B* by convention. After mining the barrier pillar, the mobiles tramming down the entry are referred to as the "No. 1" (left side) and "No. 2" (right side) units. Mobiles maneuvered through the crosscut are designated as the "No. 3" (pillar line side) and "No. 4" (solid pillar side) units.

The size and shape of the pillar remnants, back wing, and pushout stump (figures 2*C* and *D*) can vary from pillar to pillar. The riskiest process during pillar extraction is pushout removal. Some operators routinely try to extract 60% or more of the pushout, conditions permitting; others do not attempt to remove the pushout. This decision is based on mining conditions, past experiences with equipment entrapments, and safety considerations. In general, the more competent the roof, the more likely the pushout is removed. Operators who typically remove the push will abandon it if the stump shows signs of excessive

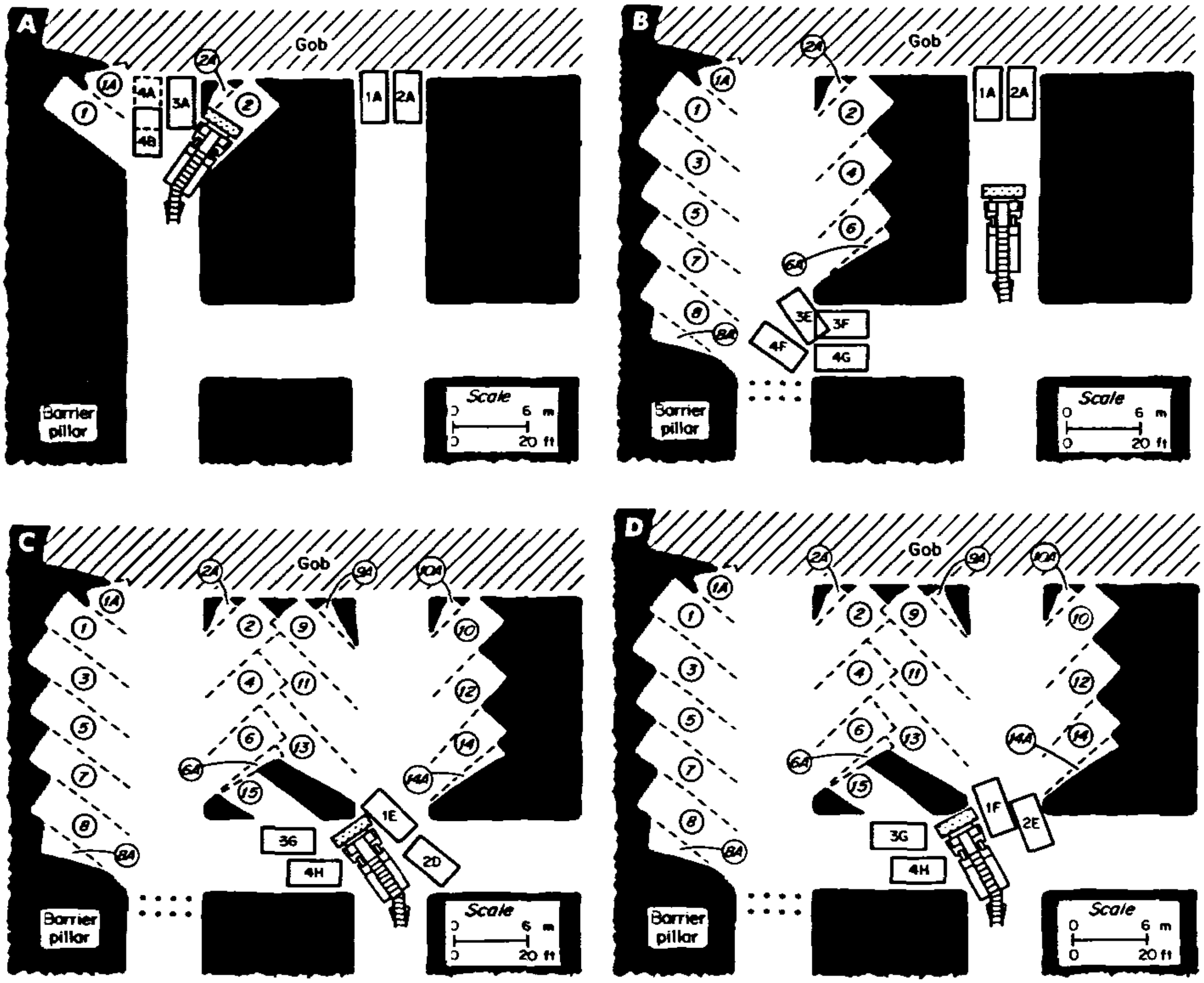

Figure 2.—Christmas tree extraction method. *A*, lifts 1-2A. *B*, lifts 1-8A. *C*, lifts 1-push; pushout removal with units 1 and 2 in tandem. *D*, lifts 1-push; pushout removal with units 1 and 2 staggered.

weight. It should be noted that when attacking the pushout, most operators situate the mobiles so that the roadway is from 3.7 to 4.3 m (12 to 14 ft) wide. The clearance is so restrictive that the ripper head has bent mobile canopies. Bit marks were also observed on a few canopies. If the push is wider than the ripper head, the sump will normally be taken through the middle of the push.

Based on operators' experiences and underground data obtained by Hay et al. [1997], the area most prone to roof falls during pillar extraction is the intersection. Operators sometimes refer to the intersection as the "critical area." During the study conducted by Hay et al. [1997], units 1 and 2 were situated in the entry just inby the intersection during back wing and pushout removal. Significant roof deflection and higher roof bolt loads were monitored, compared with an adjacent instrumented intersection, where timbers were used to extract a pillar. Therefore, Hay et al. [1997] concluded that units 1 and 2 should be placed in the intersection as much as possible to protect miners and equipment. It is important to note that MRS units 1 and 2 were positioned inby the intersection when the 1995 fatality occurred in Mingo County, WV (figure 3). The fatal accident happened during the mining of the last lift in the pillar. To enhance intersection stability, some operators position mobiles 1 and 2 in tandem, as shown in figure 2C, prior

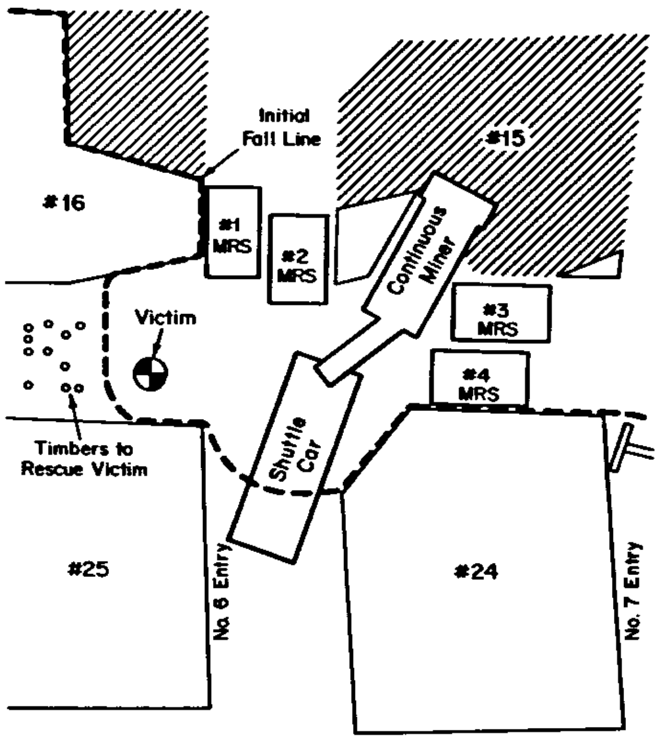

Figure 3.—MSHA drawing of fatal roof fall accident [Vance et al. 1995].

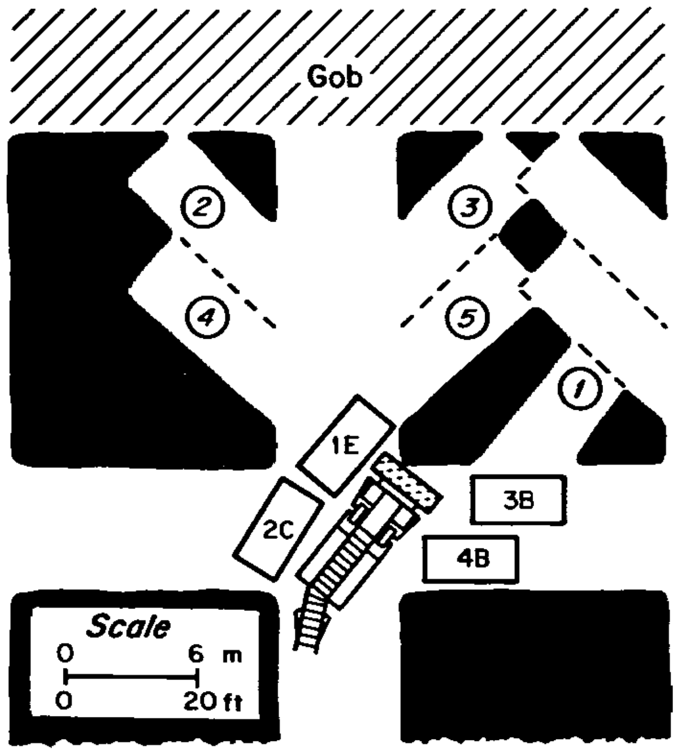

Figure 4.—Modified Christmas tree method.

to pushout removal. Other operators stagger units 1 and 2 side by side in the intersection as much as possible (see figure 2*D*). In figures 2*C* and *D*, lift 11 is a 14-m (46-ft) extended cut. In certain MSHA districts, the length of an extended cut (measured from the rib-side column of bolts) cannot exceed 14.8 m (40 ft).

A variation of the usual Christmas tree lift sequence is illustrated in figure 4, where lift 1 is taken from the back wing (also called bottom of the block). Mobile units 3 and 4 are then moved to locations 3B and 4B and pressurized. Some operators indicated that this positioning enhances intersection stability prior to the mining of the left and right wings (lifts 2-5). However, some State and Federal roof control specialists expressed the concern that the removal of the back wing lift first actually reduces intersection stability, which is critical.

OUTSIDE LIFT METHOD

The extended-cut outside lift method (figures 5*A* through *C*) generally has been used under less than 120 m (400 ft) of cover. Entry spacings are typically about 15 m (50 ft) with crosscuts on 25-37 m (80-120 ft) centers. One complaint from operators concerning this method is that the smaller pillars contain less coal; therefore, the equipment spends more time moving from pillar to pillar. As a result, some operators prefer that the pillars be as long as possible, with the major constraint being ventilation on development. A few operators have oriented the pillars in what is sometimes referred to as the "laid-down" position. In other words, the long axis of the pillar is perpendicular, not parallel, to panel development. This panel design increases the number of stoppings and roof bolts required on development, but is sometimes chosen because it reduces belt move and haulage time.

Some operators prefer the outside lift method because most power cables exit continuous miners in a right rear position. Therefore, miner operators tend to position themselves on the right side of the continuous miner. During the outside lift pillar extraction, the miner operator's positioning gives him or her an excellent line of vision. A few operators believe that this method is safer than the Christmas tree method because the continuous miner operator is less tempted to move further forward to observe the mining of the left wing.

Under weak roof conditions, some operators also prefer the outside lift method because the unsupported span (width) of the mined-out area is smaller compared with the area opened up with the Christmas tree method. In addition, the outside lift method provides added protection to the continuous miner because a solid coal pillar is nearby. Further support can be

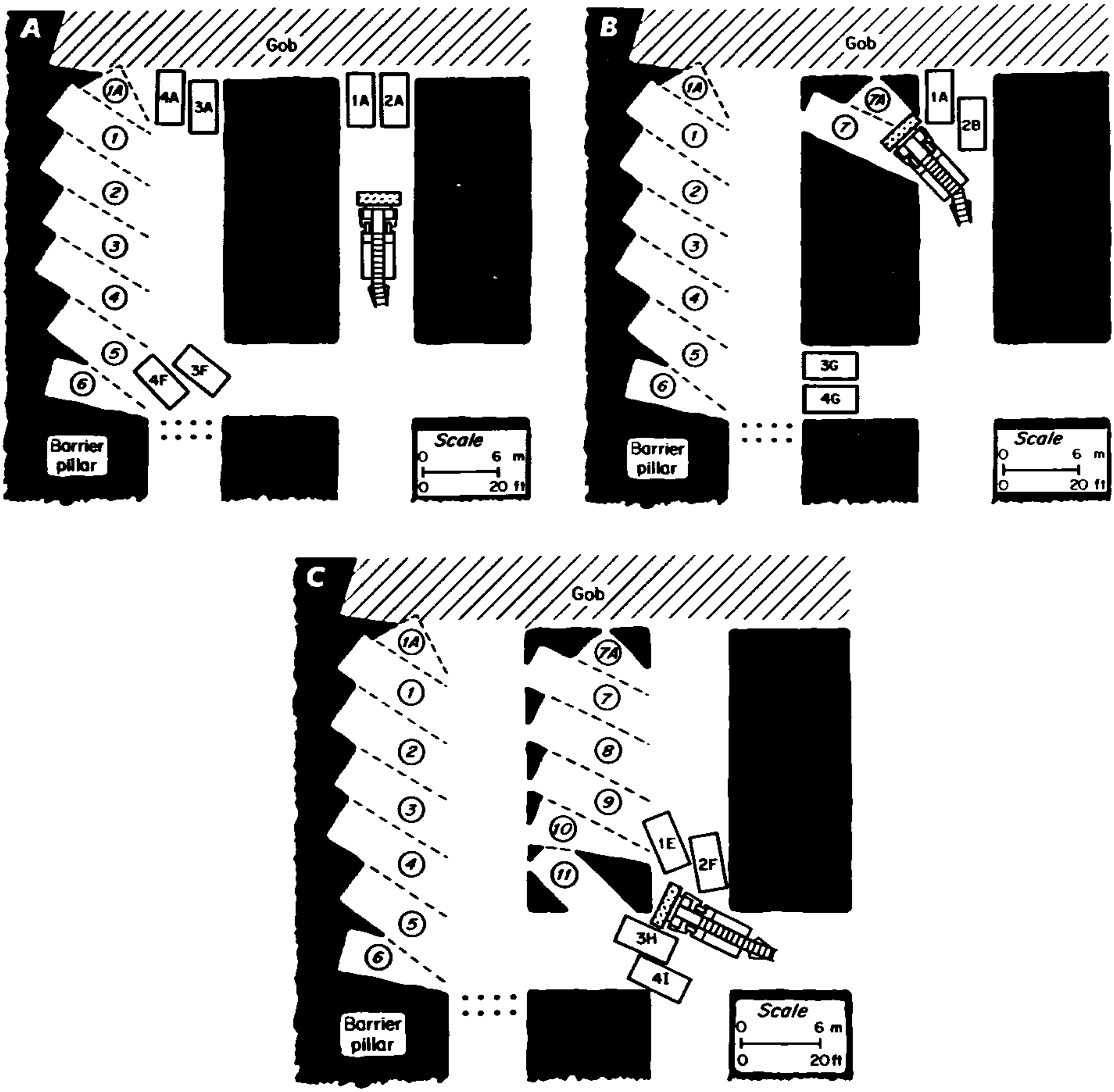

Figure 5.—Outside lift method. *A*, lifts 1-6; *B*, lifts 1-7A; *C*, lifts 1-push.

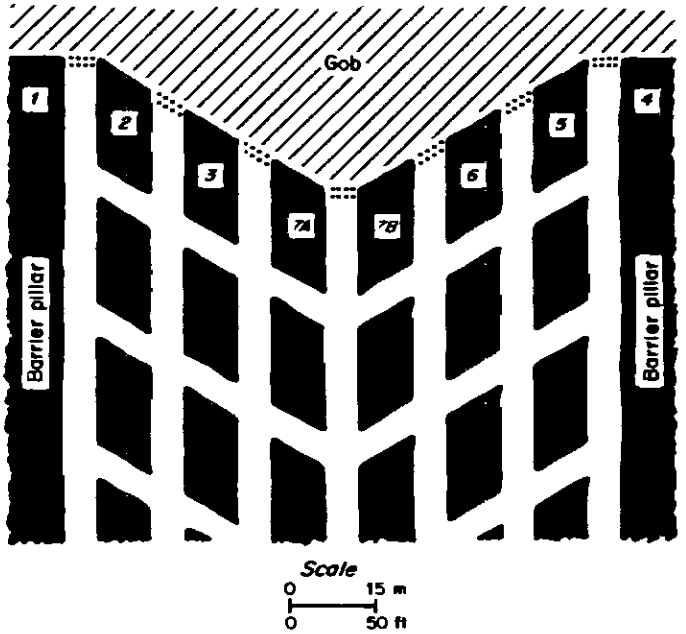

Figure 6.—Herringbone panel design.

obtained under weak roof conditions if remnants are left at the back end of the lifts. One disadvantage to the outside lift method compared with Christmas treeing is that the lift lengths are usually longer (deeper). Prolonged exposure while mining deeper lifts subjects the continuous miner to greater risk.

EXTRACTION WITH CONTINUOUS HAULAGE

The Christmas tree and outside lift methods have been used in combination to extract the parallelogram-shaped pillars (figure 6) that are developed using continuous haulage. Crosscuts are driven on approximately 60° angles to facilitate the movement of bridges and carriers. This panel configuration has been referred to as the "herringbone" or "turkey foot" design. Common entry centers range from 16 to 18 m (52 to 58 ft), with crosscuts on 25- to 27-m (81- to 90-ft) centers. Barrier and production pillars can be extracted as shown in figure 6, or pillars can be mined from right to left, then from left to right. After the mining of lifts 1 and 1A (figure 7*A*), unit 4 is trammed 2.1 m (7 ft) outby and pressurized. Lifts 2 and 2A are then removed from pillar 2. These lifts are removed to reduce the length of lift 7 shown in figure 7*B*. Mobile units 3 and 4 are positioned and pressurized at locations E and F, respectively, during breaker installation (figure 7*A*).

If poor ground conditions occur, they normally develop in the center or belt entry because the center pillars being mined are surrounded by gob on three sides, as shown in figure 7*C*. Figure 7*C* also displays mobile positioning during pushout removal in pillar 7B. A single pushout is usually removed from either pillar 7A or 7B. The push is taken from whichever fender is least loaded. The other fender (pillar 7A remnant) is left intact to function as a breaker during equipment removal. If both fenders exhibit severe loading, no pushout is taken. A laid-down version of this design has also been tried by one operator. A high incidence of roof falls in the belt entry prompted this operator to change to three-way belt entry intersections (figure 8). Three U.S. operators have employed mobiles in conjunction with continuous haulage. In one operation, shift production exceeded 5,400 t (6,000 st) during barrier pillar slabbing.

PARTIAL PILLAR RECOVERY

Mobiles were used during partial pillar recovery operations in two mines visited. Managers at one mine chose partial pillaring because the shale roof was so weak that they believed that full pillar extraction was not feasible. At this operation, pillars were initially developed on 30-m (100-ft) centers. On retreat, the pillars were "L-slabbed," with 7- to 10-m (20- to 30-ft) cuts taken from the entry and crosscut (figure 9). The remnant stumps measured approximately 19 by 19 m (62 by 62 ft). Two continuous miners were used on the section, each working with a pair of mobiles. As a row of pillars was extracted, one of the miners worked from the crosscut, while the other moved from entry to entry. Mine officials were quite satisfied with the results obtained from this method.

In the other mine practicing partial recovery, a massive sandstone roof subjected the mobiles to excessive loading during full pillar recovery. At this operation, a 4.9-m (16-ft) wide diagonal split was cut through a 9- by 9-m (30- by 30-ft) pillar, which left two triangular stumps. Miners call these stumps "coal cribs" because they provide enough short-term support for the equipment to be moved safely to the next pillar before they yielded and crushed out.

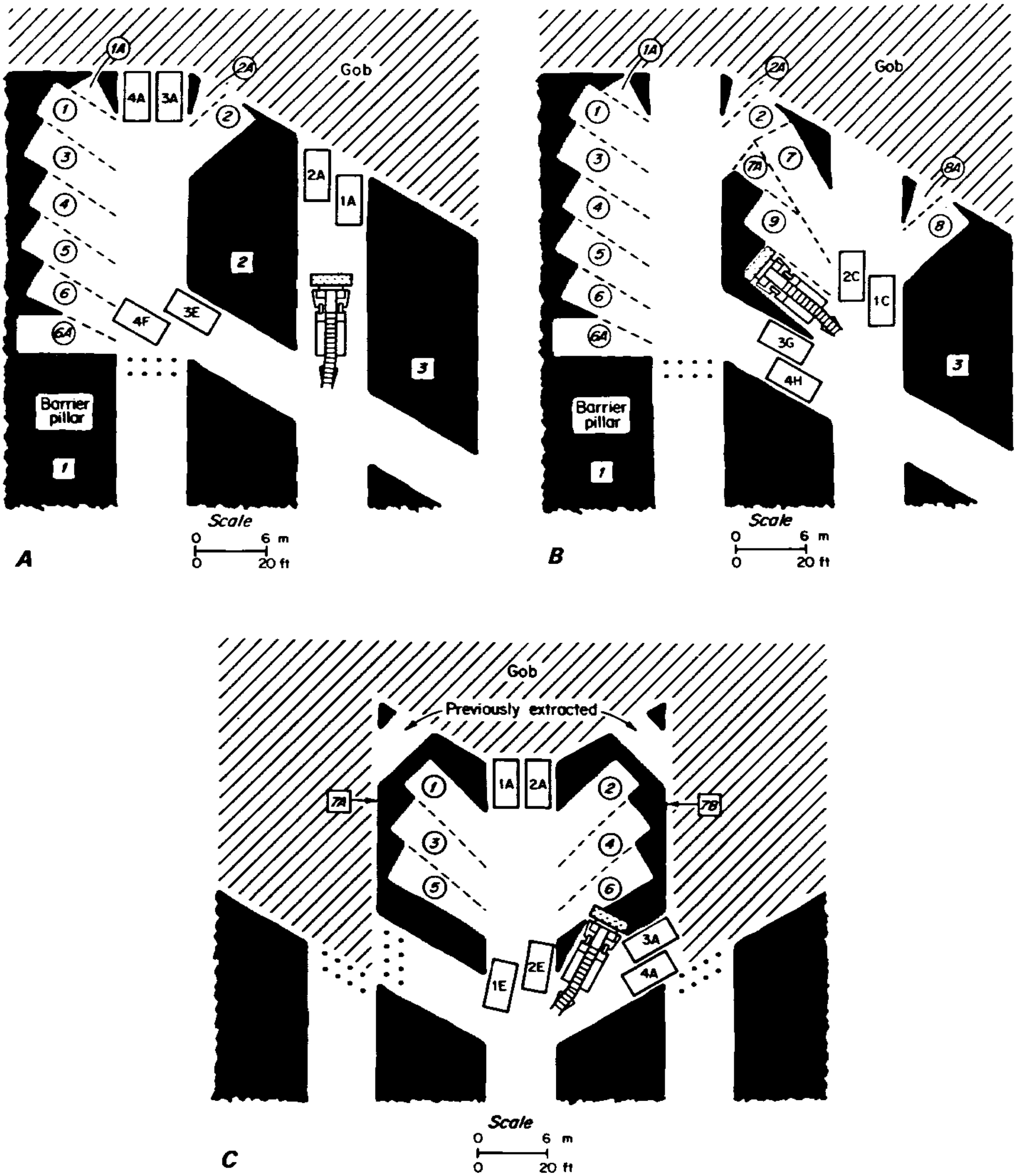

Figure 7.—Herringbone design: *A*, lift sequence for pillars 1 and 2; *B*, lift sequence for pillars 1-3; *C*, lift sequence for pillars 7A and 7B.

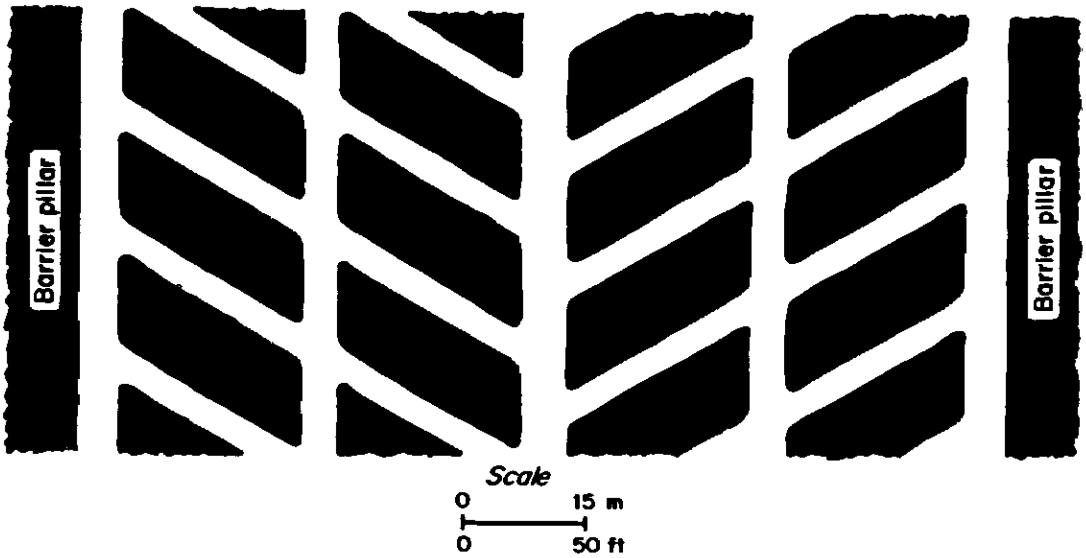

Figure 8.—Three-way intersection belt entry design.

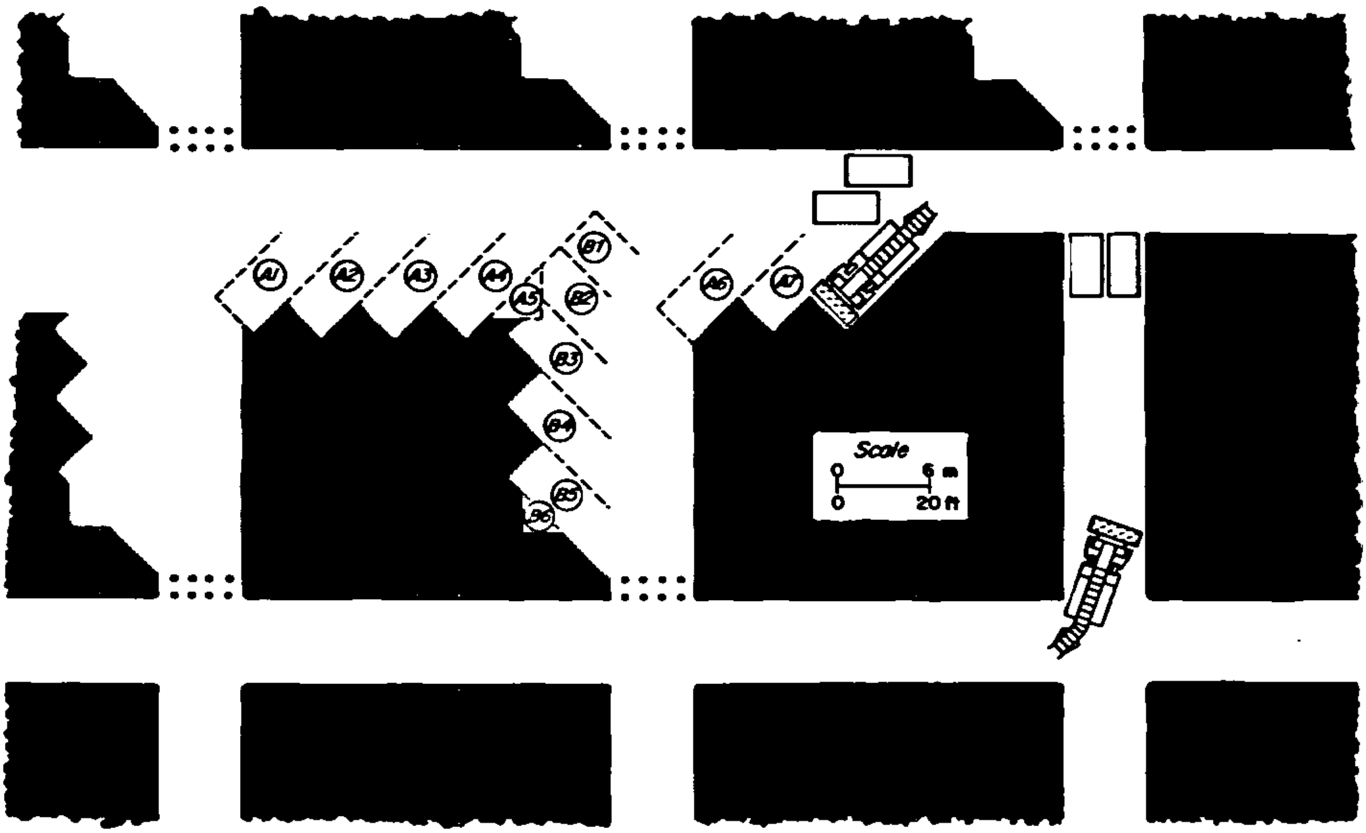

Figure 9.—Partial pillar extraction by slabbing.

OPERATIONAL ISSUES

ROOF FALLS

Roof falls or major rib rolls (side hits) can foul or bury mobiles. "Fouling" is a common term used by miners when mobiles are covered up and it requires less than 2 hours to recover them. Usually a 3.2-cm (1.25-in) high-strength steel cable or 2.5-cm (1-in) chain is attached to the mobile, and it is pulled out with the continuous miner or another mobile. A few operators with weak roof reported that weak "drawrock" sometimes fell prematurely and fouled the continuous miner while still mining in the lift. To remedy this, two mines that were visited employed fenders that separated the lift being mined from the gob. At an operation in Pennsylvania, the fender was initially fairly substantial, but it was extracted as the lift was completed (figure 10). An operation in Kentucky left 0.6-m (2-ft) fenders between lifts. These fenders were not extracted, and they provided enough support to complete the lift and remove the continuous miner before the fenders crushed out.

Major roof falls that bury mobiles may necessitate extensive cribbing and rebolting to rehabilitate the area, drilling and shooting, and a miner retriever (crab). A common mistake is to lower the canopy of the buried mobile in an attempt to tram it out from under the rock. This practice usually aggravates the problem, and mine operators have suggested that one or two cribs should be set along each side of the mobile before the canopy is lowered. Major roof falls under massive sandstone roof rock, especially during first cave conditions, can subject the mobiles to impact (shock) loads. This shock loading can cause hydraulic cylinders to swell, mushroom, or even bend. This damage occurs when the rock burst valves are unable to release sufficient hydraulic fluid to prevent the excessive buildup of hydraulic pressure. If sufficient fluid is released, the mobile becomes inoperative. Shock loading has also sheared lemniscate pins.

Numerous operators mentioned problems associated with hillseams (also called mountain cracks and surface breaks). Hillseams usually occur under shallow cover in sandstone roof rock. Parallel and intersecting hillseams can segment the roof into huge isolated blocks. Massive roof falls can occur when the coal pillars supporting these blocks are extracted. Several machines have yielded, been buried, or been severely damaged because of hillseams. Mining strategies under these conditions include leaving sufficiently sized pillar remnants to support the roof. Also, because cover is normally shallow, operators room out on 12- by 12-m (40- by 40-ft) centers near the outcrop and do not recover the pillars. One mobile operation in eastern Kentucky was mining under a massive sandstone main roof that would not break. First attempts at retreat mining were terminated due to squeeze conditions. Pillaring plans, which factored in hillseam locations, were later developed. As reported by Unrug et al. [1991], controlled systematic caving was achieved.

OPERATOR TRAINING

All of the coal mine operators visited indicated a need for practical, hands-on training. Training is required around the clock and can take from 2 to 6 weeks depending on the crew and conditions. One of the most common mistakes during training is mobile advancement. Many operators reported that mobiles best work in pairs, thereby providing protection to one

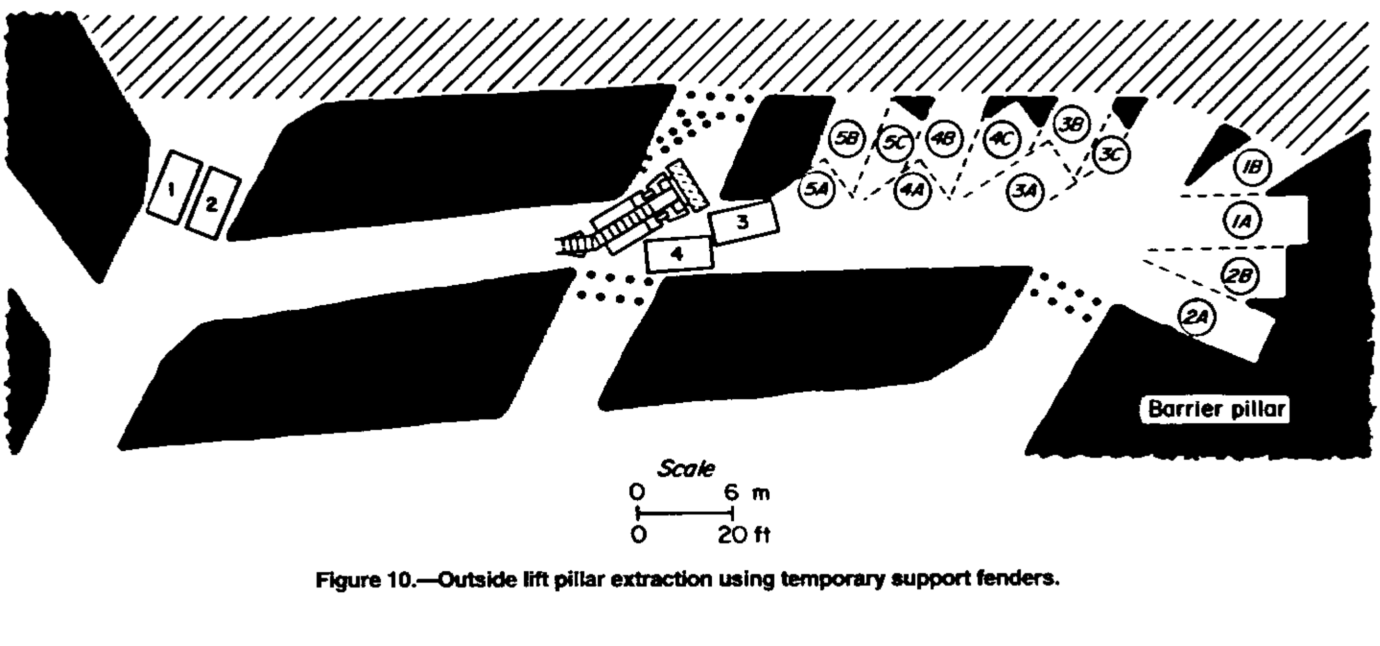

Figure 10.—Outside lift pillar extraction using temporary support fenders.

another. When moving mobiles during the mining of a pillar, it has been recommended that the machine be advanced no more than one-half the length of a canopy, or approximately 2.1 m (7 ft) from the canopy tip of the adjacent machine, and then pressurized. The second mobile, which is now protected by the first, can then be lowered and trammed forward. Mobile operators tend to advance one mobile too far and not leapfrog them, which has caused mobiles to be buried. Also, the canopy should not be lowered more than necessary to clear roof obstructions during advancement.

OPERATOR POSITIONING

After section personnel become familiar and comfortable with mobiles, it is not uncommon to hear miners say that "a mobile can pick up the whole mountain." It is important that miners do not position themselves in potentially hazardous areas because of this overconfidence and false sense of security. Leaning against the mobiles or standing in the intersection during the later stages of pillar recovery has been discouraged. During the final stages of recovery, some operators have made it a company policy that mobile and other nonessential section personnel be outby the intersection, in the entry of the next pillar row to be mined. At one mine visited, the superintendent remarked that "all it took was one gob override outby the canopies to convince the miners to stay out of the intersection."

PRESSURE GAUGES

Two pressure gauges are mounted on each mobile (figure 1). These gauges are visually monitored by operating personnel to determine loads and rates of loading on the units. Since the first fatality on an MRS section, considerable emphasis has been placed on the size of gauges. Some mobile operators have mentioned that it is necessary to stand close to the mobiles to read standard gauges. Other operators expressed that even the 10-cm (4-in) diameter gauges are of adequate size and can be read easily from 9 m (30 ft) away. Gauges are constantly monitored to determine loads and load development rates on the mobiles. Common sense modifications, which have made gauges easier to read, include the mounting of flood lights to illuminate the gauges and/or the adherence of reflective tape on the gauges' glass covers to mark a critical load threshold. At one operation, the positioning of the reflective tape depends on the roof rock type being mined under. The Spokane Research Center, MRS manufacturers, and others are currently working to develop lighting systems that can be seen from farther distances. Green, yellow, and red pulsating lights will indicate different total load levels or stages of loading. Additionally, a light-emitting diode bar graph will indicate rates of loading on individual units. Prototype lighting systems will initially be placed on the MRS units during the underground testing phase.

MACHINE RELIABILITY

During this study, operators indicated that mobiles were very reliable. Most operators cited cut power cables due to roof spalling or rib rolls as the most frequent cause of downtime. When mining in thicker reserves, high ribs are usually more hazardous and troublesome than the roof. At one mine visited, a 3-m (10-ft) high rib rolled onto the continuous miner's deadman switch while the miner was deep in a lift. While recovery efforts were underway, the roof deteriorated and a major roof fall occurred. Also, cable handling and hanging is more cumbersome in high coal, and concern has been expressed regarding the mobile operator's positioning when cables are detached from the mine roof after the lift has been taken. Breakaway cable-holding devices have recently become available. Dialog has begun with equipment manufacturers on permissible battery-powered mobiles, which has greatly interested mine operators.

RECOVERY AND PRODUCTION CONCERNS

Mobile usage has enabled a few operators to retreat mine reserves that could not be mined previously due to poor ground conditions. A mine operator in Boone County, WV, mentioned that previous attempts to retreat mine using a timber plan had failed because of poor roof conditions. He stated that caving would occur so quickly that it endangered the miners. Attempts to pillar using mobiles have proven successful in controlling premature caving. Another operator noted that past pillaring attempts with a conventional timber plan had failed because of weak floor conditions. The timbers punched into the floor, and the section would go on a squeeze. These same reserves were later successfully pillared using mobiles, which exert less ground-bearing pressure than wood posts because the crawler tracks distribute the load to the mine floor more uniformly. Coal recovery rates as high as 85% to 95% have been reported when using mobiles.

Mobile usage also assists operators in meeting production goals. Contrary to popular opinion, most of the mines contacted reported that shift production is usually higher on advance than during retreat when timbers are used. This is especially true when supersections are used on development. One major coal producer estimated that during retreat mining with timber supports, 20% less coal is mined per shift than during panel development. Some of the production decrease is attributable to downtime while setting timbers, practicing caution, and waiting for the roof to cave. Most of the operators indicated that when mobiles are employed, shift production can improve to approximately 90% to 115% of what it is during panel development. Decreased production during retreating operations has prompted some operators to run supersections with mobiles or continuous haulage in conjunction with mobiles. A few operators using the extended-cut outside lift method have reported a slight production decrease when they switched to mobiles. This occurred because the pillars are typically smaller and, therefore, contain less coal, and considerable time is lost tramming the units. These operators have continued mobile usage, however, because of their safety advantages.

PROCEDURAL VARIATIONS

Procedures governing MRS usage are addressed in each mine's roof control plan. In some MSHA districts, if one mobile becomes inoperative, the section is down until the unit is again functional. In these districts, the mine operator should consider having an approved conventional timbering plan so that mining can continue. At one mine visited, a faulty solenoid on a mobile idled the pillar line. The section squeezed and all the mobiles were entrapped. In one district, pillaring can continue with three mobiles; however, mining of the back wing and pushout are prohibited. Eight posts or two cribs are set in lieu of the No. 4 machine. Mobile No. 3 and the posts or cribs are set just outside of the intersection in the crosscut prior to mining the left or right wing. The district's position is that this scenario is safer than setting 3-m (10-ft) timbers, and operators have applauded this decision. In four MSHA districts, mines have approved plans to use only two mobiles in conjunction with timbers. Figure 11 shows mobile and post positioning during back wing removal for an outside lift plan. At least one approved combination mobile/timber plan has been approved for the Christmas tree pillar extraction method. Mobile units 1 and 2 are positioned in the same locations, as shown in figure 11. Two rows of posts on 1.2-m (4-ft) centers are also set so that the roadway width into the push is 5 m (16 ft) or less.

In two districts, plans have been approved that do not require entry breaker posts. To prevent miners from wandering into the gob, one of these districts requires a recoverable, permissible, battery-powered pulsating light to be mounted on a tripod at eye level midway down the entry. The other district requires that at least eight roof bolts on 1.2-m (4-ft) centers be installed in lieu of breakers. These bolts must be at least 0.3 m (1 ft) longer than those installed immediately outby and anchored at least 0.3 m (1 ft) into competent strata. In addition, access to the gobbed-out area must be restricted at the outby end of the unmined pillars by devices, such as chain link fencing, roping, or barrier ribbons. Reflectorized warning streamers, at least 5 cm (2 in) wide by 0.9 m (3 ft) long, are suspended from the roof at or near the restrictive devices. The other districts require the setting of eight entry breaker posts. These breakers are usually knocked out with the mobiles prior to mining the first lifts. Most of the operators expressed dissatisfaction with the requirement that entry breaker posts be installed when using mobiles. They insisted that breakers served no function, especially in competent roof, and that setting breakers subjected mine personnel to unnecessary risk. Two operators who believed that breakers were helpful were mining under weak roof. Their decision was based on previous experiences with the gob overriding the breakers, which necessitated the abandonment of lifts.

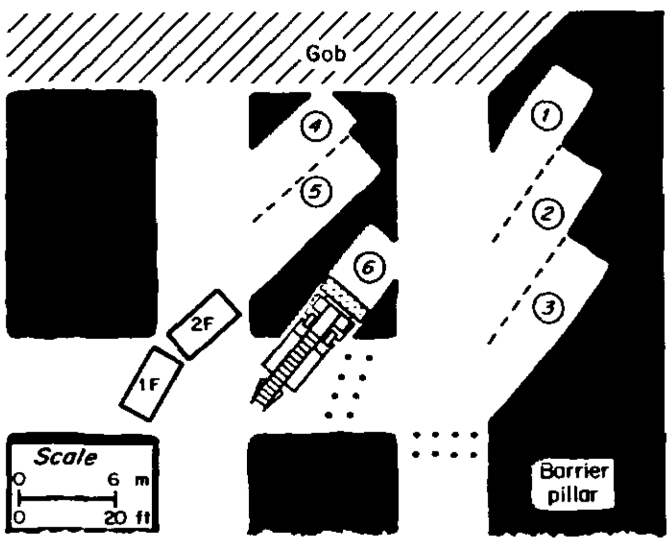

Figure 11.—Combination mobile/timber plan.

SETTING PRESSURES

The active loading capabilities of an MRS can be a significant advantage if properly used. Ideally, the support should be set against the roof with just enough force to close any gaps within the immediate roof structure. Excessive force has damaged the bolted horizon and promoted roof beam failure outby the canopy tip. The Spokane Research Center conducted an extensive field study monitoring MRS and roof bolt loading during pillar extraction [Hay et al. 1997]. Results indicated that adjacent roof bolt loads decreased when the mobiles were pressurized, which was expected. However, when the canopies were lowered, load was transferred to the bolts, and load increases up to 11 kN (2,500 lbf) were recorded. This increase in bolt load did not cause the bolts to yield in this particular mine, but the possibility exists, especially on a pillar line. Hydraulic setting pressures on the instrumented mobiles were normally 10 MPa (1,450 psi).

Setting pressures ranged from 6.9 to 30.3 MPa (1,000 to 4,400 psi) at the mines visited. The support force applied to the roof by an MRS is the product of the hydraulic pressure multiplied by the leg cylinder area. For example, an FMRS with a bore (inside cylinder) diameter of 25.4 cm (10 in) will exert a force of 2,803 kN (315 tons) with a setting pressure of 13.8 MPa (2,000 psi). An ABLS with a bore diameter of 21.8 cm (8.6 in) will require 18.8 MPa (2,730 psi) to provide the same setting force. If the same hydraulic setting pressure is used, the support force is equivalent regardless of the ABLS model or whether the hydraulic cylinders are two- or three-stage [Hatch 1996]. Regarding the FMRS units, the set force is different for two- versus three-stage hydraulic cylinders given the same set pressure [Howe 1996].

Some mines have found that weak shale top can be damaged by high setting forces. Hairline cracks can develop, mechanical bolts can "pop" and fail, and loose rock can become dislodged. At one mine, an MRS operator was injured by spalling shale roof while pressurizing the canopy. The operator was standing close to the machine, and company policy now mandates that MRS operators stand back when the canopy is being set. In addition, the setting pressures were reduced from 13.8 MPa (2,000 psi) to 10.3 MPa (1,500 psi), and no problems have occurred since. It has been recommended that mobile operators periodically check the setting pressure. Pressure bleed-off can occur if the floor is soft or if there is excessive floor gob. If bleed-off occurs, the MRS should be repressurized.

LOADS AND LOADING RATES

Operators cited several factors and conditions that have imposed increased loads on mobiles. In two operations visited, mining had been previously conducted in an upper seam. Excessive machine loading occurred while mining under remnant barrier pillars. Another reported source of mobile loading was underdesigned pillars, which had low stability factors. During retreat mining, pillars are subjected to development, front abutment, and sometimes side abutment loading. If pillars are to be mined safely and efficiently, all anticipated loading conditions should be considered during the design process [Mark and Chase 1997]. MRS loading can also be induced by excessive floor heave.

In general, mobiles operating under weaker shale roof rock have experienced lower loads. Pressure increases after the canopy was set were in the range of 3.4 to 4.1 MPa (500 to 600 psi) and, at this point, the roof normally breaks. Conversely, numerous mobiles operating under massive sandstone roof, which tends to cantilever, have yielded. At one mine visited, mobiles have been used under both sandstone and shale roof rock. The operator stated that, on average, load pressures are 1.4-2.1 MPa (200-300 psi) higher under sandstone roof rock, other factors being equal.

During the mining of a pillar, most of the operators indicated no significant load development on the No. 1 and No. 2 units during the mining of the first few lifts. Hay et al. [1997] monitored increased loads on units 1 and 2 as mining progressed during a lift and as the pillar size was reduced during successive lifts. Operators experienced maximum loading during pushout removal, with pressure increases ranging from 3 to 31 MPa (500 to 4,500 psi). The No. 3 unit sustained the greatest loads and suffered the most damage because of side hits. The No. 4 unit, which is normally situated along an unmined pillar, experienced the least loads and damage. Periodically, some operators switch the No. 3 and No. 4 units. During the mining of the first rows of pillars in a panel, prior to establishing a first cave, most operators reported no significant mobile load development. However, a few operators noted load increases of 2-7 MPa (300-1,000 psi) higher than normal. In order to establish a first cave and minimize outby loading, pillars at these operations are mined as completely as possible, which included pushout removal. Some of these operators discontinue pushout removal after the first cave.

Technical specialists and operators agree that the critical factor is not the amount of load, but rather the loading rate. Loading rates and magnitudes varied from mine to mine. Most operators commented that the decision to remove section personnel and equipment based on steady, rapid loading conditions is a judgment call based on past experiences. One operator reported that it was time to back out the continuous miner, shut down, and listen when 1.4-2.1 MPa (200-300 psi) pressure increases occurred every 5 min over a 15-min interval. Another operator indicated that if the pressure jumps 1.4 MPa (200 psi) once, and then again, it is time to lower the canopies and tram out because a fall normally always occurs. Other operators cited instances during pushout removal when, in a matter of seconds, 21-28 MPa (3,000-4,000 psi) pressure increases occurred. The continuous miner and personnel were removed, and a fall never occurred. The mobiles later inched their way out. During the mobile field monitoring investigation conducted by Hay et al. [1997], no significant MRS load increase was detected when the canopy of the adjacent mobile was lowered. In other mines, operators noticed immediate increases in the 2-14 MPa (300-2,000 psi) range. Significant load transfer to the adjacent machine can cause it to yield. Whether or not load is transferred is a function of roof geology and the pillars' stiffness. Some operators reported that the pressure gauges seldom showed any change during the mining cycle, and a few operators even observed pressure decreases. No pressure change implies that the force exerted by the roof has not exceeded the setting force applied by the MRS. A decrease in MRS pressure might occur if the machine settled into the floor or roof, or if there was a leak in the hydraulic system.

When mobiles are subjected to consistent load increases, operators practice one of two strategies. Some operators remove section personnel, the continuous miner, and lastly the mobiles prior to the cave. Other operators leave the mobiles in place until after the fall to breaker it off. These operators indicated that when the mobiles start creaking and taking weight, they are performing their function. Even when the yield valves open and the hydraulic fluid is spewing out, these operators insist that it is still not time to lower a canopy. In fact, one of the advantages of an MRS is that it continues to maintain a high support load even though it is yielding. Some operators reported that lowering the canopy removes the support from the roof and allows the roof cave to override the MRS's.

CONCLUSIONS

By replacing roadway, turn, and crosscut breaker posts, MRS usage enhances the safety of section personnel by (1) providing a more effective ground support, (2) reducing worker exposure near the gob edge, and (3) eliminating a major cause of material handling injuries. Compared with wood posts, mobiles provide better roof coverage and improved stability. To achieve the full advantages of mobiles, they must be employed properly. Training and careful attention to standard operating procedures are essential. Through the experience at different mines, strategies have been developed to cope with the hazards posed by hillseams, weak roof, and first falls.

During the later stages of pillar recovery, the area most prone to a roof fall is the intersection. Placement of mobile units 1 and 2 in the intersection during pushout removal enhances roof stability. Positioning of nonessential personnel outby the intersection better ensures their safety.

Mobiles have been employed during full and partial pillar recovery operations. Most pillars are recovered using either the Christmas tree or outside lift method. In some MSHA districts, roof control plans have been approved that do not require breaker posts. A few districts have approved plans that allow pillar extraction with fewer than four mobiles.

Setting pressures in the mines visited ranged from 6.9 to 30.3 MPa (1,000 to 4,400 psi). The most common setting pressure for mobiles is 10 MPa (1,500 psi). In some instances, higher setting pressures have damaged weak shale roof rock. Operators reported that maximum loading occurred during pushout removal. MRS loading is typically higher under sandstone roof rock than shale.

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